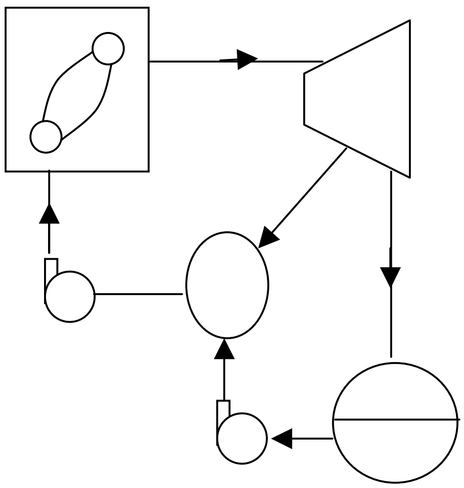
Rankine Cycle with Regeneration (OFWH) – **Due Tuesday 1/27/04**

Consider a steam power plant that operates on a regenerative Rankine cycle and has a net power output of 150 MW. Steam enters the turbine at 15 MPa and 600 C. The condenser pressure is 10 kPa. Assume that both the pump and the turbine are isentropic. Steam is extracted from the turbine at 0.5 MPa and sent to an Open Feedwater Heater (OFWH).

a) Label each component and state point. Sketch the cycle on a *T-s* Diagram



b) Complete the following table of the thermodynamic properties

State	Pressure	Temperature	h (kJ/kg)	s (kJ/kg)	Phase Description
1					
2		***********			
3					
4		***********			
5					
6					
7					

c) Find the mass flow rate through the cycle (kg/s)

d) What is the thermal efficiency of this cycle?

e) Using the MIN/MAX Function in EES find the optimal OFWH pressure.

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{Rankine Cycle with Regeneration}

{Boiler Pressure - 15 MPa
 Condenser Pressure - 10 kPa
 OFWH Pressure - 500 kPa
 Steam enters the turbine at 500 C }

{P_OFWH = 500}

{State 1 - sat liquid leaving the condenser }

P[1]=10
x[1] = 0
h[1]=enthalpy(steam,P=P[1],x=x[1])
s[1]=entropy(steam,P=P[1],x=x[1])

{State 2 - Isentropic Pump from 1 to 2 }

s[2]=s[1]
P[2] = P_OFWH
h[2] = enthalpy(steam,P=P[2],s=s[2])

{State 3 - sat liquid leaving the OFWH }

P[3]=P[2]
x[3] = 0
h[3]=enthalpy(steam,P=P[3],x=x[3])
s[3]=entropy(steam,P=P[3],x=x[3])

{State 4 - Isentropic Pump from 3 to 4 }

s[4]=s[3]
P[4] = 15000
h[4] = enthalpy(steam,P=P[4],s=s[4])

{State 5 - superheated steam entering the turbine }

P[5] = P[4]
T[5] = 600
h[5] = enthalpy(steam,P=P[5],T=T[5])
s[5] = entropy(steam,P=P[5],T=T[5])

{State 6 - isentropic turbine from 5 to 6 }

s[6]=s[5]
P[6]=P_OFWH
h[6] = enthalpy(steam,P=P[6],s=s[6])

{State 7 - isentropic turbine from 6 to 7 }

s[7]=s[6]
P[7]=10
h[7] = enthalpy(steam,P=P[7],s=s[7])
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{Calculate the mass flow rate of the steam extracted from the turbine
entering the OFWH }

m*h[6]+(1-m)*h[2]=h[3]

{Calculate the specific work of the turbine}

wT = (h[5] - h[6]) + (1-m)*(h[6]-h[7])

{Calculate the specific work of the pump }

wP = (h[4]-h[3])+(1-m)*(h[2]-h[1])

{Determine specific net work and use that information with the given output power of 150 MW
to find the mass flow rate }

wnet = wT-wP

m_dot*wnet = 150000

{Find qin and then calculate the thermal efficiency }

qin = h[5]-h[4]

eta_th = wnet/qin

{Finally in order to use the MIN/MAX function you must comment out the P_OFWH}

{Select "min/max" under the "Calculate" heading. Choose to maximize eta_th, and set
P_OFWH as the independent variable. The program will ask for an initial guess on P_OFWH
and upper and lower limits. }

{Maximum thermal efficiency when the OFWH pressure is 1332 kPa }

Unit Settings: [kJ]/[C]/[kPa]/[kg]/[degrees]

η_{th} = 0.4632
$\dot{m}$ = 119
qin = 2721
wP = 16.65

m = 0.2402
P_{OFWH} = 1500
wnet = 1260
wT = 1277

Parametric Table: Table 1

	P_{OFWH}	η_{th}
Run 1	500	0.4609
Run 2	611.1	0.4616
Run 3	722.2	0.4622
Run 4	833.3	0.4626
Run 5	944.4	0.4629
Run 6	1056	0.463
Run 7	1167	0.4632
Run 8	1278	0.4632

Parametric Table: Table 1

	P_{OFWH}	η_{th}
Run 9	1389	0.4632
Run 10	1500	0.4632